CHAPTER 4

FUTURE CLIMATES OF THE NEW ENGLAND REGION

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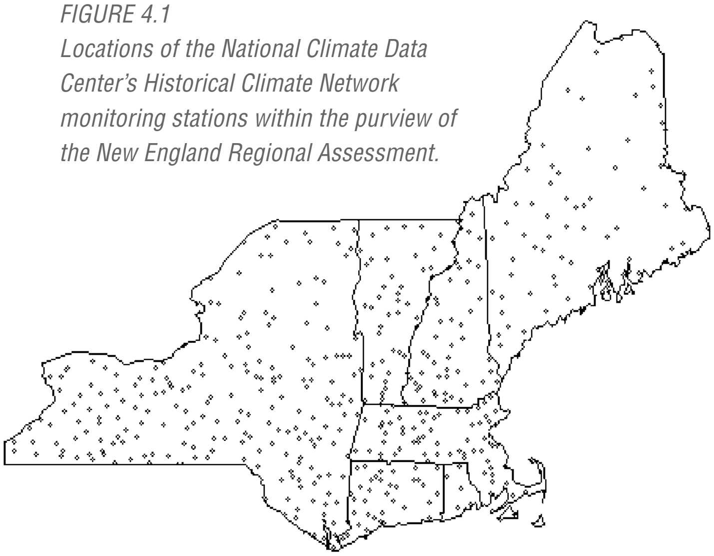
It is becoming increasingly clear that significant global climate change will result if the concentrations of greenhouse gases continue to rise. This fact has led the international community to negotiations on the control of the emissions of greenhouse gases (the Kyoto Accord), and has led to the U.S. National Assessment of the potential impacts of future climate change on this country. However, local and regional projections about the timing, magnitude, and nature of future climate changes remain uncertain and difficult to assess. The magnitude of future concentrations of greenhouse gases will be determined by human actions yet to be taken, and there are scientific uncertainties in the climate system itself, which are largest at a local scale and over short periods of time (decades to centuries).

The mandate of the New England Regional Assessment (NERA) is to identify and evaluate the potential impacts of future climate change on various components of the New England region. To address the future climatic conditions, the US National Assessment has provided data of both historical climate and future climate estimates or “scenarios” for the New England region. The historical climate data for the region is provided for context. The scenarios of possible future climate change have considerable uncertainty and are provided as a minimum basis with which to begin to assess the potential impacts of possible future climate change in New England and upstate New York.

The selection of the specific General Circulation Models (GCMs) for use in this assessment process must also recognize both time and human constraints. For these reasons, common climate scenarios were used by each region and sector, forming the minimum basis for the overall assessment process.

There are many aspects of climate that are important to New England. This first assessment has focused its efforts on three climate variables for consideration as impact agents: (1) monthly minimum temperature; (2) monthly maximum temperature; and (3) monthly precipitation.

FIGURE 4.1
Locations of the National Climate Data Center’s Historical Climate Network monitoring stations within the purview of the New England Regional Assessment.



Historical Climate Parameters

Understanding the nature and extent of climate historically throughout the New England Region is important for interpreting future climate scenarios. The historical climate data used in this assessment were obtained from the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP) Phase 2 historical gridded record. This regional data set, from well over 300 monitoring stations across New England and upstate New York (Figure 4.1), is comprised of data from the National Climate Data Center’s U. S. Historical Climate Network (HCN), and from the USDA’s Natural Resources Conservation Service’s SnoTel stations for monitoring precipitation at high-elevations. These data have been spatially interpolated onto a 0.5˚ X 0.5˚ latitude/longitude grid. The New England region consists of 128 VEMAP grid cells.

These models simulate climate in response to changes in the concentrations of greenhouse gases over time.

Climate Scenarios

In the production of scenarios of possible future climate change, NERA uses the projections from two global climate models used in the National Assessment: the Canadian Centre for Modeling and Analysis's Canadian Global Coupled Model (CGCM1 – hereafter called the Canadian Model), and the United Kingdom's Hadley Centre for Climate Modeling and Analysis's model (HadCM2 – hereafter called the Hadley model). These models simulate climate in response to changes in the concentrations of greenhouse gases over time. Both models assume a 1% (of current levels) per year increase in greenhouse gas concentrations. The cooling affect of sulfate aerosols is incorporated by increasing the Earth's atmospheric albedo (brightness, a measure of reflectivity).

About the Graphics

The finest temporal resolution of the data used in this analysis is monthly. Monthly data were averaged within each year to produce annual mean time-series and averaged within each season to produce seasonal time-series for each parameter. Historical and model output presented for the annual time-series include the annual values (thin line) and the10-year running means (thick line), while seasonal output graphs only present the 10-year running mean.

A gap along the x-axis (year axis) between the historical and scenario curves is produced by this calculation. This gap results at the beginning and end of the time-series data where a centered 10-year running mean can not be computed. A gap in the time-series also occurs along the y-axis (parameter axis) and results from differences in the historical and modeled outcomes. The modeled results do not include historical values as input for calibration, so model outcomes are not expected to coincide precisely with the historical outcomes.

Seasonal time-series data were used to show parameter variation within a year. Here, Winter is represented by averaging the months January-March, Spring by April-June, Summer by July-September, and Fall by October-December. In addition to the characteristics of the annual time-series graphics, the seasonal time-series graphics have been scaled to facilitate seasonal visual comparison. Visual comparison of seasons across parameters should be used with caution, because of the change in y-axis scaling.

Annual Minimum Temperature

Both the Canadian and Hadley models suggest that the average annual minimum temperature of the New England region will increase in both the near-term (i.e. 2030) and long-term (i.e. 2100) future (Figure 4.2). However, the

Regionalized Historic and Scenario Mean Annual Minimum Temperature

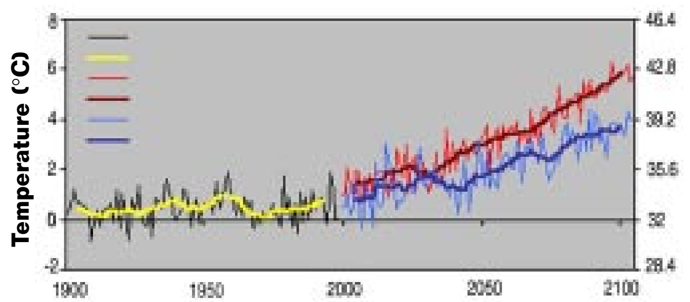


FIGURE 4.2
Graph of the 10-year running average of regional historic and modeled average annual minimum temperatures. There is no indication of a regional increase in minimum temperatures that departs from the range of exhibited variation. Both model estimates agree in predicting sustained increasing minimum temperatures that exceed expected variations. The Canadian model suggests greater increases in minimum temperatures than the Hadley model. Regional values were calculated by averaging the yearly mean values across all 128 VEMAP2 grid cell elements comprising the New England Region.

Both the Canadian and Hadley models suggest that the average annual maximum temperature of the New England region will increase in both the near-term (i.e. 2030) and long-term (i.e. 2100) future.

Regionalized Historic and Scenario Mean Annual Maximum Temperature

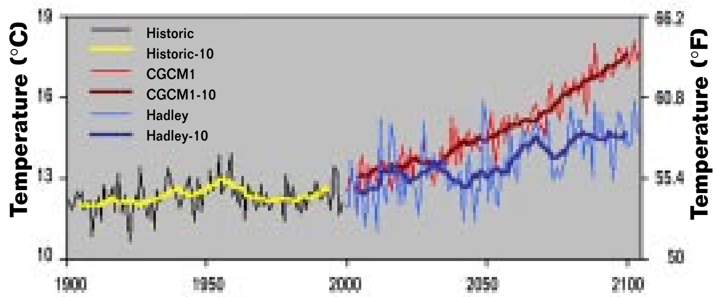


FIGURE 4.3
Graph of the 10-year running mean of regional historic and scenario average annual maximum temperatures. Model estimates agree in projecting sustained increasing maximum temperatures into the future that departs from the range of exhibited variation. The Canadian model suggests greater increases in maximum temperatures than the Hadley model.

Regionalized Historic and Scenario Mean Annual Precipitation

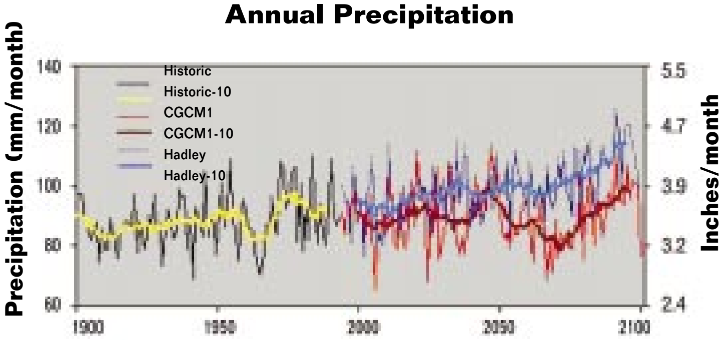


FIGURE 4.4
Graph of the 10-year running mean of regionalized historic and scenario average annual precipitation. There is a slight regional increase in the historic precipitation, however, large, rapid departures from any norm have occurred as exhibited by the mid-1960s drought. Model estimates do not agree in estimating potential future precipitation. The Canadian model suggests lesser increases in precipitation than the Hadley model.

models differ in the magnitude of minimum temperature change. Both models suggest the region may increase by 1˚ C (1.8˚ F) by 2030 but the Hadley model indicates a 3.1˚ C (5.6˚ F) rise by year 2100, while the Canadian model indicates a 5.3˚ C (9.5˚ F) rise over the same time period. These changes are very large relative to the historical record of minimum temperature variation that has occurred over at least the past 1000 years (Figure 3.6).

Annual Maximum Temperature

Both models suggest that the average annual maximum temperature of the region will increase in both the near-term (i.e. 2030) and long-term (i.e. 2100) future (Figure 4.3). However, as with the minimum temperature, the models differ in the magnitude of maximum temperature change. Both suggest an average annual maximum temperature increase of 1.5˚ C (2.7˚ F) by 2030 and from 2˚ C (3.6˚ F) to 5˚ C (9˚ F) by 2100 (Hadley and Canadian models, respectively). Both of these scenarios suggest large temperature increases in the future compared to the past 100 year record of maximum temperatures.

Annual Precipitation

Historically, annual precipitation in the New England region has varied widely and has included times of drought (Figure 4.4). Note the prolonged drought that characterized the mid-1960s. Embedded within this range of variability, lies a long-term trend (i.e. 100 years) of a modest (4%) increase in precipitation. The Hadley model predicts a continuing increase in precipitation (an approximate 30% increase) without evidence of the type of drought seen in the 1960s. The Canadian model suggests little long-term increase in precipitation (an overall increase of approximately 10%), but large fluctuations in precipitation with events similar to the drought of the 1960s.

Seasonality

Most of the seasonal trends were similar to the annual trend for each parameter (Figure 4.5). In every season, both the Canadian and Hadley models predict substantial warming, and the Canadian model generally predicts greater amounts of warming than the Hadley model. Exceptions to this occur in the Summer and Fall minimum temperatures, where the models suggest approximately equal amounts of warming. Precipitation is

In every season, both the Canadian and Hadley models predict substantial warming…

projected to increase substantially in every season except Spring in Hadley, and does not have a substantial trend according to the Canadian model in any season. Both models illustrate the potential for continued interannual year-to-year variation in seasonal precipitation of magnitudes that are similar or larger to variations experienced in the record.

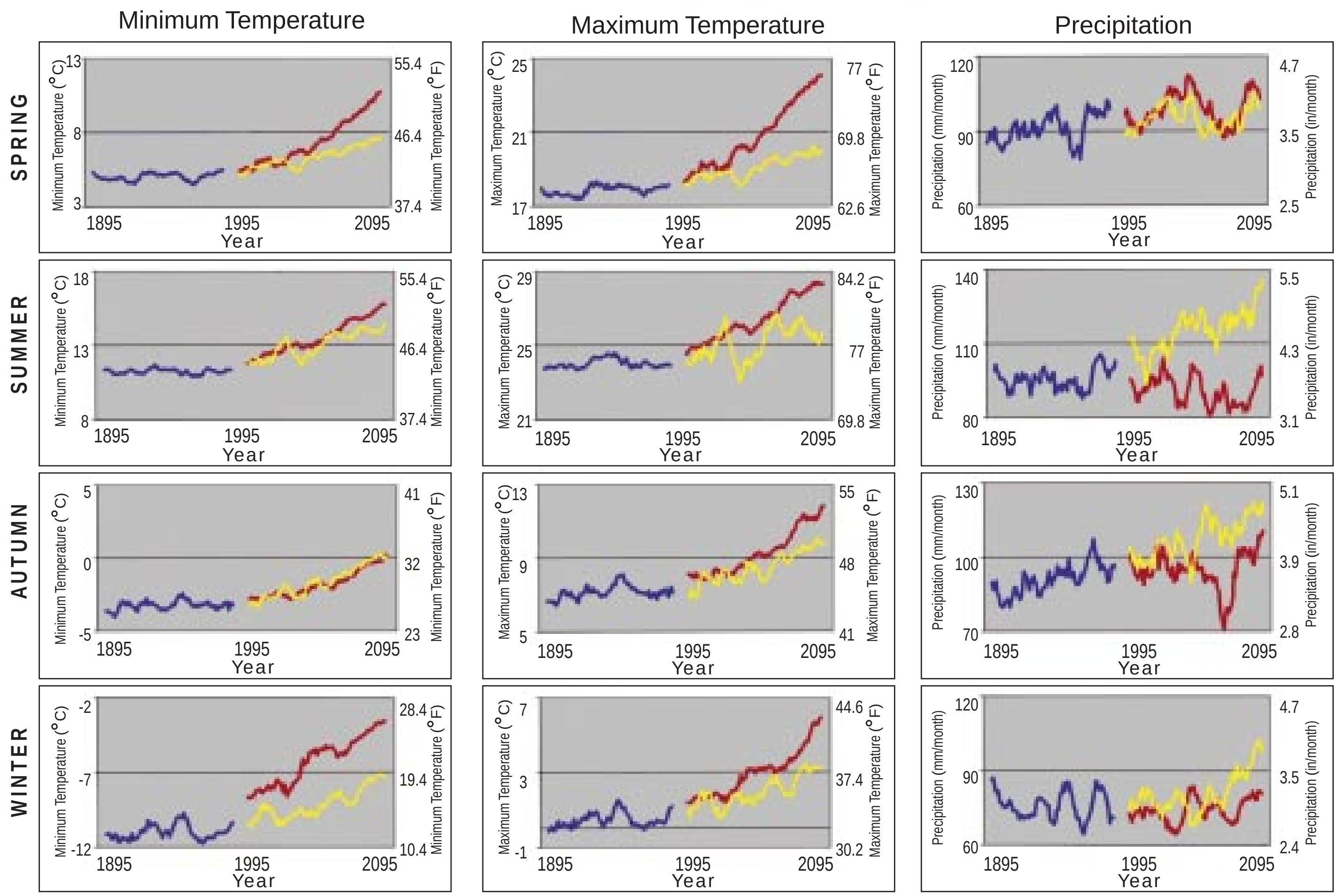


FIGURE 4.5

Seasonal trend graphs (10 year running means) for the 1895-1993 VEMAP2 historical gridded data and two model "scenario" data sets from 1994-2100.

KEY: historical Canadian Hadley

Sp=Spring; SU= Summer; AU- Autumn; WI=Winter.

The Canadian model predicts greater temperature increases inland than along the coastal regions, a result in disagreement with historic findings.

Spatial Variation

The climate models show differing amounts of spatial variation in the parameters investigated (Figure 4.6). Region-wide variation in the long-term temperature anomalies is greater in the Canadian model than in the Hadley model. The Canadian model predicts greater temperature increases inland than along the coastal regions, a result in disagreement with historic findings (Chapter 2). In contrast, the Hadley model shows little to no spatial variation in temperature changes across the entire region. In terms of precipitation regimes, the Hadley model shows a greater absolute precipitation difference, but also a greater degree of regional heterogeneity compared with the lesser absolute precipitation and clinal variation exhibited by the Canadian model.

Model Evaluation for the New England Region

The model data sets used for the New England Regional Assessment represent some of the best available. However, the down-scaling of much larger-scale global climate models to finer regional scale (used in this analysis) is problematic. Many of the geographic (i.e. coastal) and topographic (mountains) variables that are known to influence our regional weather and climate

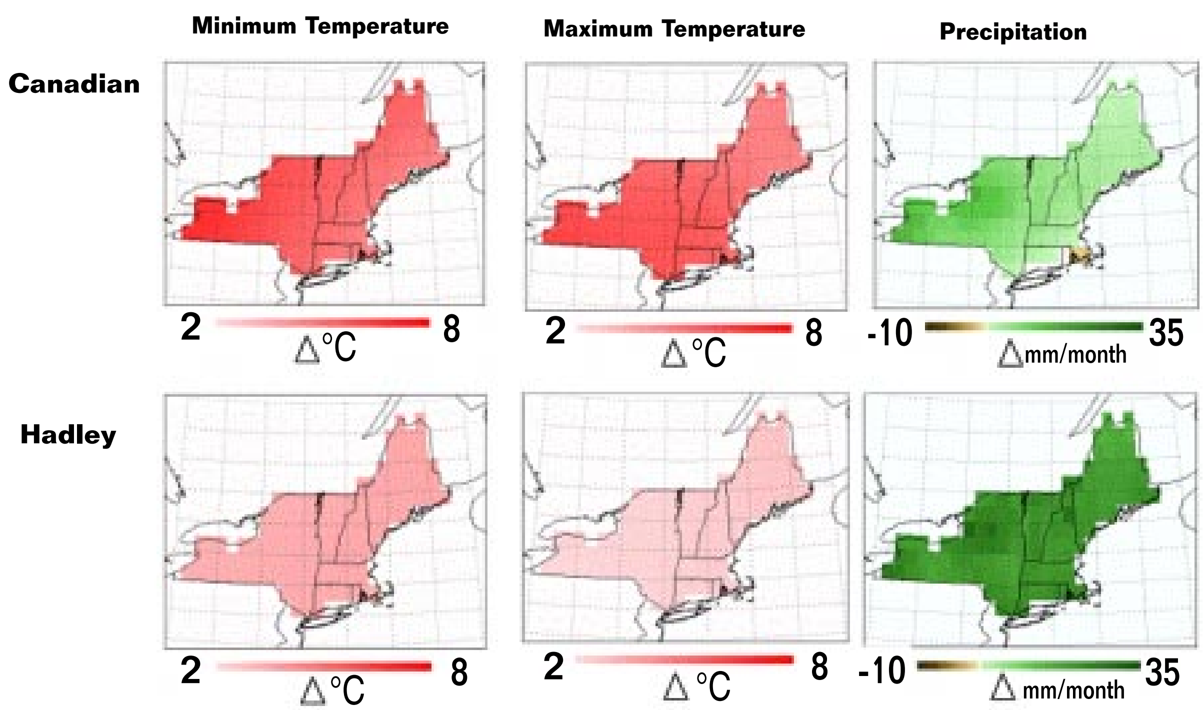


FIGURE 4.6
Graphs of New England and upstate New York spatial variation of Minimum Temperature, Maximum Temperature and Precipitation for the Canadian and Hadley models. All differences (anomalies) are computed as the [2090 - 2099] mean minus the [1961-1990] mean.

The changes projected by either model, if realized, would be much larger than the climate variation experienced by the New England region in the last 10,000 years…

(Chapter 2) are not considered in global-scale models such as the Canadian and Hadley. For this reason, the regional projections presented in this chapter must be considered "best approximations" based on what is available in the late 1990s. Both models present us with "What if" future projections (What if the region warmed by 6° F?). Clearly there is a great need for regional climate models to be developed that account for regional variability at a scale known to affect weather and climate.

Newest Climate Models Reproduce the Recent Climate Record and Identify the Human Influences

Recent work has used a new global version of the Hadley climate model to simulate recent historic global temperatures and to assess the relative importance of natural and anthropogenic (human) factors on the temperature patterns of the last 140 years (1860-1999). The model is able to simulate the global temperature record of this period very well. This is possible only when both changes in natural and human factors that affect climate are included. Changes in natural factors such as variation in solar irradiance and volcanic activity are necessary to duplicate the warming trend observed in the early part of the century. However, such natural factors alone fail to simulate temperature records in the later half of the 20th century. Human factors such as the increasing concentrations of greenhouse gases in the atmosphere are needed to explain the warming trend over the past 30 years. The ability of the model to accurately simulate the last century of warming gives one confidence that models are potentially useful representations of the climate system with which to make projections of the future. The large influence of human factors such as the increases in greenhouse gas concentrations on the climate system in the latter part of the century reaffirms the expectation that further warming is to be anticipated with continued increases in greenhouse gases that will result from "business as usual" combustion of fossil fuels.

Summary/Conclusions

Significant climate change in this century is considered an increasingly serious possibility. To provide a basis for an assessment of the potential impacts of future climate change on New England, NERA has used the regional output from two global climate models as scenarios of possible future climate change in the New England region. These models are not perfect, but represent the best scientific scenarios available, and should be viewed as possible outcomes. Both models predict substantial warming and substantial changes in precipitation for the region if greenhouse gas emissions continue to rise at 1% per year into the future. The Canadian model predicts a more dramatic warming with large fluctuations in precipitation, but without an increasing long-term trend. The Hadley model predicts a less dramatic warming, and a trend toward dramatic increases in regional precipitation. Both models suggest that minimum temperatures will rise at a slightly greater rate than the maximum temperatures. The changes projected by either model, if realized, would be much larger than the climate variation experienced by the New England region in the last 10,000-20,000 years.